

How Free is a Fall That Occurs in Real World?

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ABSTRACT

Observing a rain fall or falling leaves or tossing pizza dough in air, can give some thought of free fall. But how free are they? These types of questions can come to anyone's mind when you see something falling in air to the ground. What is a free fall and how is different than not being a free fall? In my present research, I studied and tested concepts of free fall using various types of objects those are different in shape, size, weight, and volume. I tested them for free fall by dropping them from same height to find out how accurately they follow free fall conditions or if they do not follow free fall theory then what are the causes. Is there any experimental error that is causing a fall not to be a free fall, or it is natural or something else? I also tested how weight and height can affect free fall of objects. After experiments, it came out that objects those are very light in weight or very large in volume or have ability to hold air in it due to their shape show deviation from free fall concepts and counted as non-free fall objects.

INTRODUCTION

In everyday life, we see various falls which can be a rock falling from a top of the hill as shown in the Image 1 or a ball falling from the balcony of the 2nd floor, or a toy fell from a table or a bird feather or a hair is falling to the ground. Based on how large or small object is or how light or heavy object is or how much air object can hold, the fall can be affected. In this research, our goal is to find out the falls we usually see in our daily life and determine if they are free fall or not. If not, then why not. To understand the depth of the concept of whether a fall is free or not, we used different steps and methods to follow, and they are given below. We tested how time of the free fall is affected by the type, shape, size, weight of the object, and how the height of the fall plays role in free fall. Whether all falls we see in real world those occurs in everyday life are free fall or not. Is there any simpler way to measure and detect if falls are free or not without going to a tedious laboratory and performing experiments at home or school?

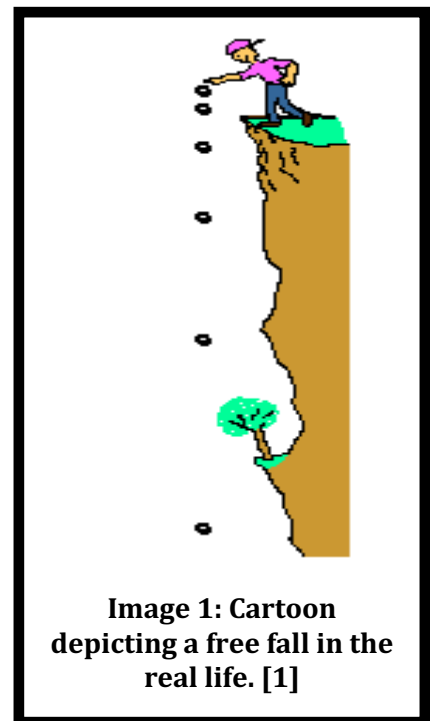


Image 1: Cartoon depicting a free fall in the real life. [1]

Our interest is to determine which objects appear to be close enough to free falling over relatively short distances such as within a household setting using household objects those are different in shapes, size, weight and dropped from different heights. Which objects would show higher value of air resistance and how this air resistance can be measured in simpler way?

What is a Free Fall?

Any fall that occurs under the influence of gravity solely is called free fall. That means if we look free body diagram (FBD) of an object, it should have one downward force which is gravity (F_g) only. If we happen to measure the gravity under which object is falling, and if it comes as gravity of Earth as 9.81 m/s^2 , it means the fall is free fall. Free fall doesn't show any other additional force acting on the object other than force of gravity. It is said that in Vacuum, objects in free fall, accelerates with same rate regardless of their mass. [2]

What is not a Free Fall?

Any object that falls has more than one force acting on it which is additional force than force of gravity is called non-free fall. In other words, if the gravity under which object is falling is calculated or found by performing experiments and if it comes different than $g = 9.81 \text{ m/s}^2$ on Earth, it means fall is not a free fall. It is possible the calculated gravity for a particular fall comes either larger or smaller than 9.81 m/s^2 and it shows clear indication of either an additional force that supporting gravity or opposing gravity. Some examples can be used as windy weather, warm weather, or presence of air resistance. If object has an opposite force upward force because of air in addition to its gravitational force, it is called that object has air resistance and not falling under free fall.

Based on types of fall, object may take different time of fall indicating that whether it is a free fall or non-free fall. Our goal is to test free fall with multiple types of objects those are available at everyone's home and we use them in our daily life. They are different in shape, size, and weight and whether they show free fall or not and if not then why not.

Research Questions, Hypothesis and Variables

During these experiments, these questions are tested to find whether fall is a free fall or not. 1) How free can a fall be that occurs in real world? 2) How long does an object take to fall from a given height to the ground? 3) How the time of fall is affected by the shape of object if dropped from the same height, 4) What would be its velocity when it hits the ground? 4) Can shape, size and weight of an object change its data of free fall? 5) What applications can be seen of free fall in real world?

Before beginning experiments, the hypothesis for the experiments is: 1) Heavier object will take less time to fall than lighter object, 2) Different shape and size objects will take different time to fall, 3) Objects will hit ground with their highest speed, 4) Higher the height, longer the time of fall, 5) A general free fall may show presence of air resistance. 6) Are there simple ways of performing experiments at home or school to see how air resistance affect free fall?

The variables used in the experiments of free fall are: *Independent Variables* were Height and Objects. *Dependent Variables* were Time, Velocity, Force and Acceleration. *Controlled Variables* were Gravity, Number of repetitions, Experimental condition, Temperature and Humidity.

To understand the affect of free fall or air resistance, some modified version of Physics equations are used and tried to find simple equations to see if they can show affect of air resistance in various objects or not. The presence of air resistance shows an upward force on the object and reduces the amount of gravitational force. It can be said that there is drag force that makes object to fall slower than usual based on objects shape and size or ability to hold air. Details concepts and equations are discussed in the result and discussion section of this paper.

Materials: Materials used for free fall experiment and data collection

Following objects are used for these experiments those are available to anyone's home: Basketball, Soccer Ball, Dodgeball, Tennis Ball, Golf Ball, Bouncy ball, Marble, Paper ball, Wooden block, Wooden block with a hole, Pencil, Feather, Balloon w/o air, Thick Book, Bracelet, Balloon with air, Shoe, Plain paper, Pillow, Metallic Bowl, Closed umbrella, Duckie toy, Plastic bowl, Open umbrella, Foam cup, Paper sticker, Coffee closed cup, Paper bookmark. Notebook, Laptop, Pencil, Microsoft Office, calculator, Stopwatch, Tracker Data Analysis Software, Phone and Meterstick.

METHODS AND THEORIES

To perform experiments with household objects, following methods and steps are used.

1. Objects were weighed using a digital balance. 2. Objects were dropped from a height of 2 meters and time of fall was recorded using Three Methods: *a) Stopwatch, b) Cellphone, c) Video Analysis (using Tracker video analysis software)*. 3. Each experiment was repeated five times for accuracy. 4. 29 non-breakable objects were dropped from 2 m height. 5. To avoid air resistance, experiments were performed inside house in same environmental conditions with room temperature at 70 °F and normal humidity of 33%. [3] A device is used to find temperature and humidity of the room where experiment was performed, and the room temperature and humidity were kept identical for entire experiments. 6. Using equations of Free fall, theoretical time of fall and final velocity of objects were calculated and compared with experimental values. 7. The possible causes of errors were considered, *1) reaction time, 2) air resistance*. 8. Some objects were dropped from 1 m of height to see difference between heights of falls.

Initially, first two objects, a basketball and a wooden block were chosen first to drop from a height of 2 m and the time of fall was recorded with three different methods, 1) time from manual stopwatch as T_s , 2) time from cellphone as T_p , and 3) time from tracker video analysis as T_v . To find out what method of measuring time of fall is better, these three methods of time of fall were compared. To get the time of fall, the object was placed at the height of 2 m and then released, and time was recorded of object's fall until it hits the ground. This time is called T_{exp} . This time was recorded using three methods as described above. Each object was dropped for five times and then time data was collected and then average of the T_{exp} is found. The T_{exp} was found with stopwatch, phone, and video analysis. The stopwatch and phone used user's finger to be clicked so reaction time factor can be involved in these two methods but when T_{exp} was recorded by video analysis, no reaction time factor is found in this method as time was obtained by clicking time button.

To see what the most effective way is to find T_{exp} , the time of the fall recorded as T_s , T_p and T_v , they are compared. When difference between T_s and T_p were calculated, it came almost zero which means no matter if use manual stopwatch or phone as watch, they were same. The

time of the fall recorded with video analysis is taken by free video analysis, tracker, software to take video of a free fall of an object and then that video was analyzed to find out time of fall as T_v . After getting T_v , when T_s and T_v were compared, a difference of 0.15 s came. Then theoretical time of fall was calculated as T_{th} following kinematics and theory of free fall using equation # 2 and when theoretical time T_{th} was compared with time of fall measured by stopwatch as T_s , the difference in time came as 0.15 s. When theoretical time T_{th} is compared with the time found by video analysis T_v , no difference in time came.

After performing experiments using above steps, following theory was applied to find out theoretical time of fall, final velocity of the free fall when object hits the ground, effect of height on free fall and air resistance present in light or high-volume objects.

According to Kinematic Equations of Free fall in Physics, following equations can be given:

The height of the object when it is dropped can be given by equation # 1, the time of the fall can be given by equation # 2:

$$H = \frac{1}{2} * g * t^2 \quad \text{where } H = \text{height (in m), } t = \text{time taken in fall (in s)} \quad (1)$$

$$t_{th} = \sqrt{2 * H / g} \quad (\text{theoretical time of fall}), \quad g = \text{gravity} = 9.8 \text{ m/s}^2 \quad (2)$$

The final velocity of the object when it hits the ground can be given in the form of equation # 3, and the percent error between theoretical time and experimental time of fall can be given in the form of equation # 4:

$$V_f = g * t \quad \text{where } V_f \text{ is final velocity, } g \text{ is gravity and } t \text{ is time of fall} \quad (3)$$

$$\% \text{ Error} = (T_{th} - T_{exp}) * 100 / T_{th} \quad (4)$$

Using Newton's second law of force and motion, we can show a relationship between weight and gravity and acceleration of air resistance and force acted because of air resistance in the form of equation # 5. We can also find a relationship between experimental time of fall T_{exp} and experimental acceleration a_{exp} of free fall in the form of equation # 6:

$$F_g = M * g \quad \text{and} \quad F_{air} = M * a_{air} \quad \text{where } M \text{ is mass, and } a_{air} \text{ is acceleration of air resistance} \quad (5)$$

$$a_{exp} = 2 * H / (T_{exp})^2 \quad \text{and} \quad a_{exp} = g - a_{air} \quad \text{and} \quad a_{air} = g - a_{exp} \quad (6)$$

According to Oregon State University Publication [4], a relation can be seen in between air resistance force and final velocity of the object. From this relationship, the constant of air resistance can be found and can be compared between types of objects those are light in weight or have higher volume or have capacity to hold air. This equation can be seen as equation # 7:

$$F_{air} = -k * V_f, \quad \text{and} \quad k = -F_{air} / V_f, \quad (7)$$

k is air resistance constant, depends on shape of object and density of air (Kg/s).

RESULTS

The data of time taken in falling for all objects were recorded with three methods. The details of these can be seen in TABLE 1.

The abbreviations used for data have these meanings in the tables

T_s = Time from stopwatch, T_p = Time from phone, T_v = Time from Video analysis, T_{th} = Theoretical Time, T_r = Reaction Time, T_{exp} = Experimental Time, $T_{exp} = T_s - T_r$.

Table 1: It shows the effect of measuring time of fall by three methods, a) manual stopwatch, b) cell phone stopwatch, c) video analysis. Then it also shows how experimental time of fall is calculated by subtracting reaction time.

TABLE 1: EFFECT OF METHOD OF FREE FALL TIME											
<u>Height (H) = 2.0m</u>		<u>Tth = 0.638s</u>			<u>T = 70 °F</u>		<u>Humidity = 33%</u>		<u>Tr = 0.15s</u>	<u>Texp = Ts-Tr</u>	
#	Objects	Trials	Ts (s)	Tp (s)	{Ts- Tp} (s)	Tv (s)	{Ts - Tv} (s)	Tth (s)	{Ts - Tth} (s)	Tr (s)	Texp (s)
1	Wooden block	1	0.75	0.74	0.01	0.645	0.105	0.64	0.11	0.15	0.6
	44.66 g	2	0.82	0.84	- 0.02	0.64	0.18	0.64	0.18	0.15	0.67
		3	0.82	0.81	0.01	0.635	0.185	0.64	0.18	0.15	0.67
		4	0.76	0.76	0	0.64	0.12	0.64	0.12	0.15	0.61
		5	0.8	0.8	0	0.64	0.16	0.64	0.16	0.15	0.65
		Avg	0.79	0.79	0	0.64	0.15	0.64	0.15	0.15	0.64
2	Basket ball	1	0.75	0.74	- 0.01	0.65	0.1	0.64	0.11	0.15	0.6
	700.0 g	2	0.82	0.84	0.02	0.63	0.19	0.64	0.18	0.15	0.67
		3	0.79	0.8	0.01	0.66	0.13	0.64	0.15	0.15	0.64
		4	0.76	0.76	0	0.64	0.12	0.64	0.12	0.15	0.61
		5	0.8	0.78	- 0.02	0.64	0.16	0.64	0.16	0.15	0.65
		Avg	0.784	0.784	0	0.644	0.14	0.64	0.144	0.15	0.634

To understand from where 0.15 s time difference is coming, the reaction time of the data collector was taken. Since I was the data collector, I took my reaction time using following method and found that my reaction time is 0.15 s. To find reaction time, a ruler was dropped TEN times and data was collected for height dropped as shown in the Image 2. Then time of fall was calculated using equation # 2 as mentioned in the theory section and reaction time (Tr) was found. The details of the data for reaction time can be seen in TABLE 2. Human's avg reaction time is Tr = 0.25 s. My Tr = 0.15s. [4]

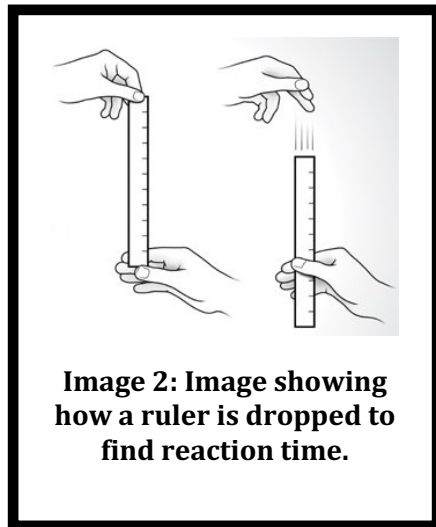
Table 2: It shows how reaction time was calculated by dropping a ruler and catching it.

TABLE 2: Reaction Time			
Starting height (h_1) = 0 m			
Ending height = h_2			
Height rules dropped = $h_2 - h_1 = H$			
Trials	h_2 (cm)	H (m)	Tr (s)
1	15.5	0.155	0.178
2	15	0.15	0.175
3	9	0.09	0.135
4	9.5	0.095	0.139
5	13	0.13	0.163
6	10	0.1	0.143
7	8.5	0.085	0.132
8	7	0.07	0.119
9	12.5	0.125	0.16
10	7	0.07	0.119
AVG	10.7	0.107	0.148
			0.15 +/- 0.01

The time of fall calculated from video analysis is from a free data analysis software called Tracker. Tracker video analysis software can be found at [5] For that, the wooden block and basketball were dropped from the same height of 2 m and video was taken using Tracker.

Then video was analyzed to find time of fall and compared it with theoretical time and experimental time of fall. The value of time found from Tracker analysis for the start and end of the fall were subtracted to find the time of free fall and it came as $T_v = 2.47 - 1.82 = 0.64$ s as can be seen in Image 3a and 3b. This time of fall does not show effect of reaction time and came as same as theoretical time. Which clearly indicates that reaction time of 0.15 s is coming into effect when time of the fall was recorded by stopwatch. The start and end time of the fall

recorded from Video Analysis can be seen in the Image 3 which shows graphs taken from Tracker analysis tool.

After observing the effect of reaction time, the effect of reaction time $T_r = 0.15$ s was subtracted from all data of time of fall those were collected from phone stopwatch for all objects those were dropped. All detailed results and calculations of how experimental time T_{exp} of

fall was found for all other objects dropped from the same height of 2 m are given below in TABLE 3. This table shows the effect of shape and size of objects on free fall.

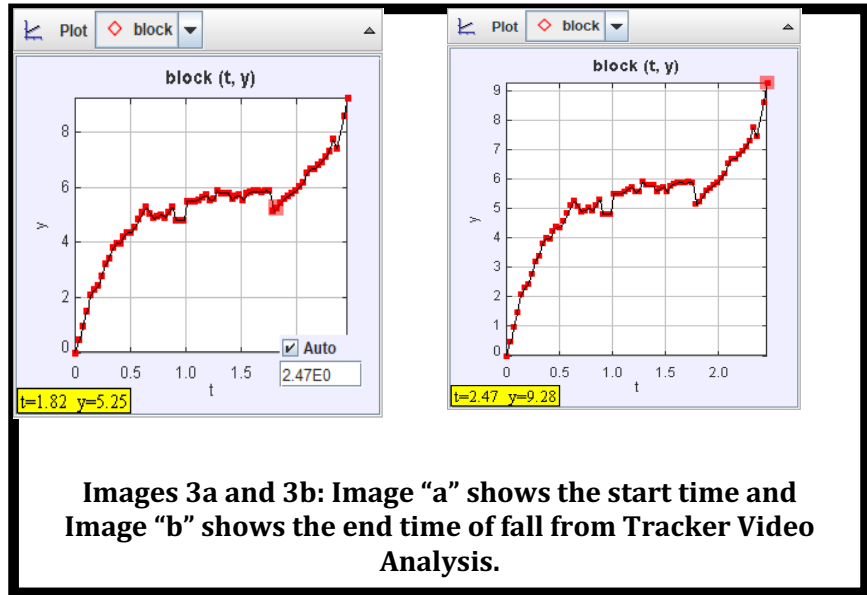


Table 3: It shows the effect of shape, size and mass on free fall and how experimental time is different than theoretical time because of the shape and size of objects those were dropped from the same height.

TABLE 3: EFFECT OF SHAPES/SIZE ON FREE FALL							
$H = 2$ m; $g = 9.81$ m/s²; $T_{th} = 0.638$ s; $V_{f th} = g \cdot T_{th} = 6.26$ m/s, $V_{f exp} = g \cdot T_{exp}$							
Objects (29)	Mass (g)	M (kg)	T_{exp} (s)	T_{exp}-T_{th}	% error in T_{exp}	V_{f_exp} (m/s)	% error in V_{f_exp}
Thick Book	1200	1.2	0.632	0.008	1.25	6.2	0.96
Basket ball	700	0.7	0.64	0	0	6.28	0.29
Soccer Ball	500	0.5	0.634	0.006	0.9375	6.22	0.65
Shoe	200.92	0.20092	0.686	0.046	7.1875	6.73	7.5
Wooden Block 2	196.7	0.1967	0.632	0.008	1.25	6.2	0.96
Closed umbrella	223.87	0.22387	0.67	0.03	4.6875	6.57	5
Open umbrella	223.87	0.22387	1.25	0.61	95.3125	12.26	95.89
Wooden block	44.66	0.04466	0.636	0.004	0.625	6.24	0.33

Wooden block with a hole	60.15	0.06015	0.632	0.008	1.25	6.2	0.96
Dodgeball	63.55	0.06355	0.636	-0.004	0.625	6.24	0.33
Tennis Ball	57.43	0.05743	0.688	0.048	7.5	6.75	7.82
Metallic Bowl	54.23	0.05423	0.674	0.034	5.3125	6.61	5.62
Golf Ball	45.97	0.04597	0.658	0.018	2.8125	6.45	3.11
Bouncy ball	6.36	0.00636	0.646	0.006	0.9375	6.34	1.23
Marble	6.22	0.00622	0.634	0.006	0.9375	6.22	0.65
Pillow	169.18	0.16918	0.604	0.036	5.625	5.93	5.35
Plastic bowl	29.9	0.0299	1.01	0.37	57.8125	9.91	58.28
Duckie toy	13.47	0.01347	0.656	0.016	2.5	6.44	2.8
Coffee closed cup	13.99	0.01399	0.632	0.008	1.25	6.2	0.96
Paper ball	4.58	0.00458	0.632	0.008	1.25	6.2	0.96
Pencil	6.17	0.00617	0.636	0.004	0.625	6.24	0.33
Foam cup	3.21	0.00321	1.128	0.488	76.25	11.07	76.77
Bracelet	5	0.005	0.63	0.01	1.5625	6.18	1.27
Plain paper	4.2	0.0042	2.098	1.458	227.8125	20.58	228.78
Paper bookmark	1.88	0.00188	1.16	0.52	81.25	11.38	81.78
Paper sticker	0.64	0.00064	1.312	0.672	105	12.87	105.6
Feather	0.07	0.00007	1.682	1.042	162.8125	16.5	163.58
Balloon without air	3.02	0.00302	0.642	0.002	0.3125	6.3	0.61
Balloon with air	3.44	0.00344	2.084	1.444	225.625	20.44	226.58

From the TABLE 3 can be seen that experimental time T_{exp} is different than theoretical time T_{th} for some of the objects. The percent error between experimental and theoretical time came very high for these objects with deviation from free fall. Final velocity was also calculated using equation # 3 as shown in the method section for all objects when they hit the ground and it came almost same for most of the objects excepts some objects those show deviations.

A graph plotted between types of objects and time taken in free fall is shown as Figure 1A. This figure clearly shows comparative results in between theoretical and experimental time of fall. It can be seen the some of the objects do not show same time of fall as same as theoretical time but have deviation from theoretical time. These objects were marked as deviated objects in this experiment.

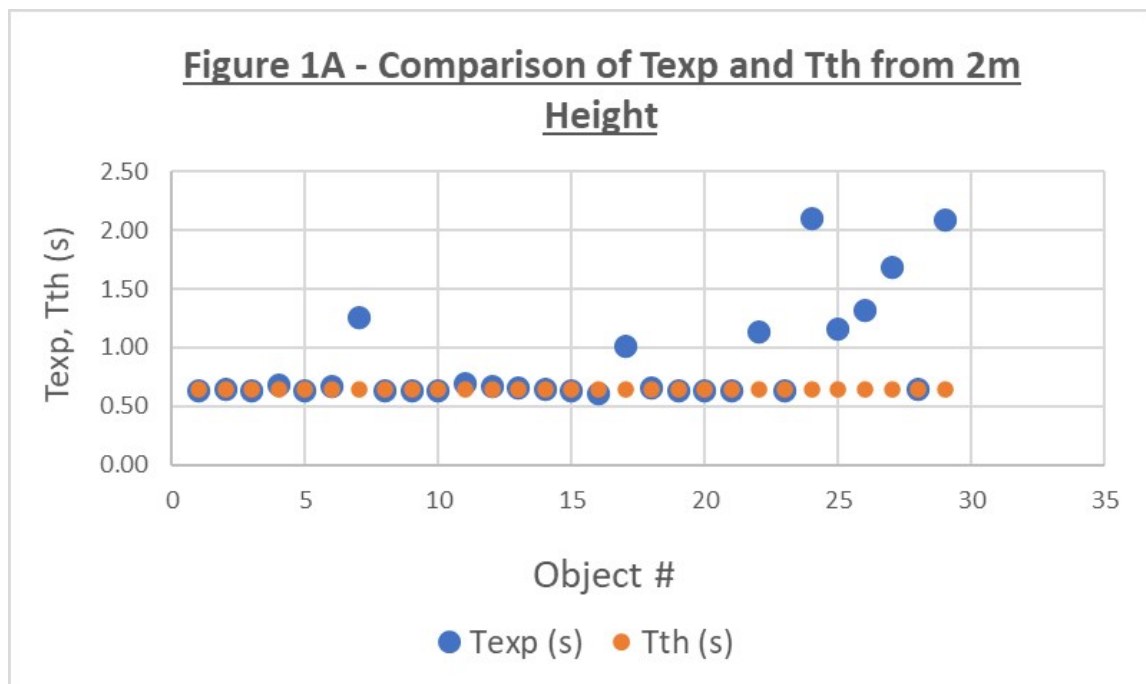


Figure 1A: It shows a comparison of experimental time of free fall with theoretical time of free fall for all objects those were dropped from the same height of 2m. Most of the objects show almost same value of experimental time of fall as theoretical time of fall but some show deviation. T_{exp} , T_{th} and Object # means Experimental time of fall, theoretical time of fall and object numbers as mentioned in the table number 3.

The percent error between experimental and theoretical time of fall was calculated following equation # 4 as shown in the method section and deviated objects showed high percent errors. The results of higher percent error in free fall time can be seen in the Figure 1B.

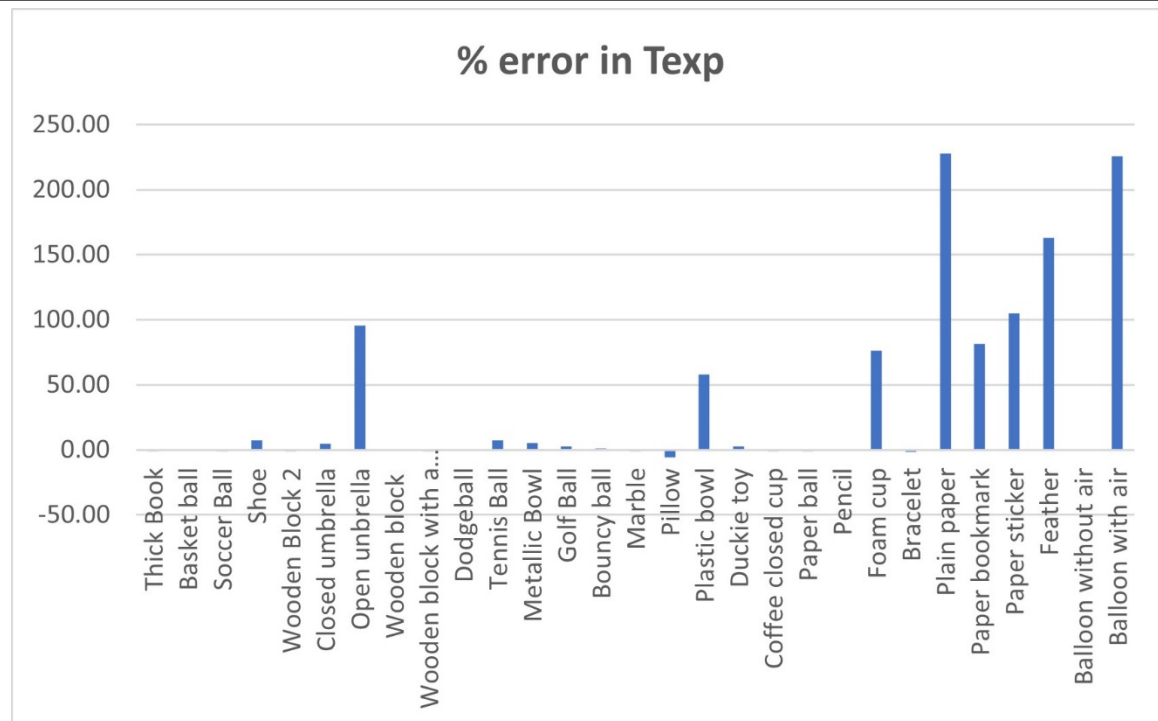


Figure 1B: It shows the percent error between experimental and theoretical time of fall for all objects on Y axis. It is clear that objects those show deviations in Figure 1 showed higher percent errors.

Later, the percent error in between experimental and theoretical final velocity was also found for all objects, and it was found the deviated objects showed maximum percent error in their final velocities. The results of higher percent error in the final velocities can be seen in these deviated objects in Figure 2A.

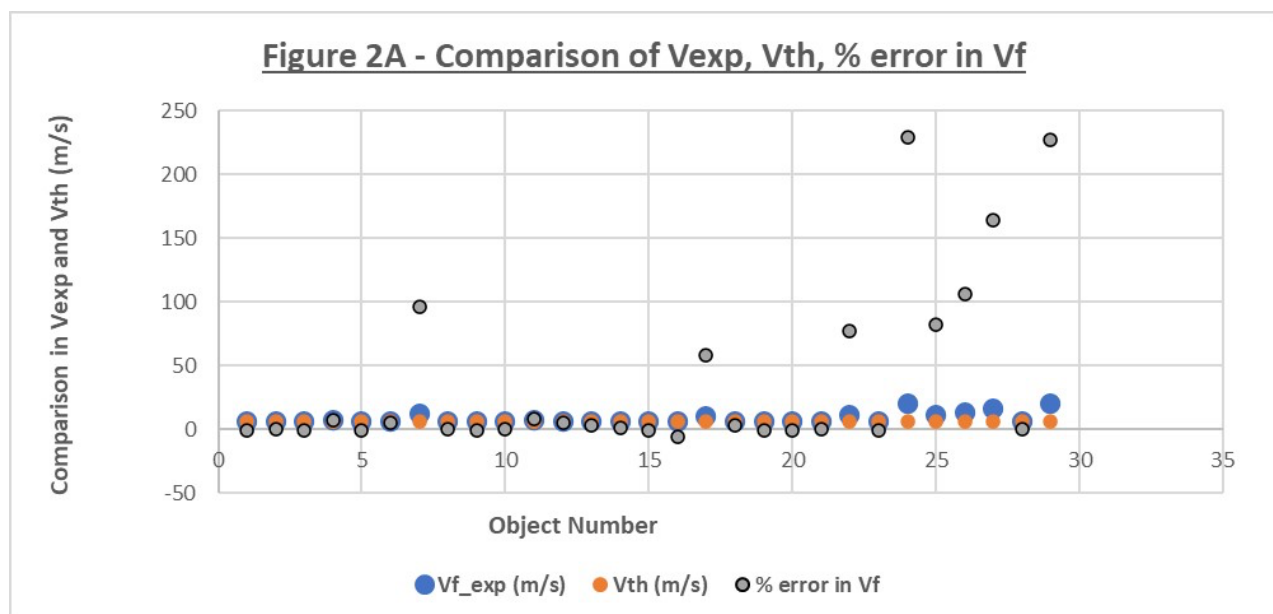


Figure 2A: It shows the comparison between experimental and theoretical values of final velocities of all objects those were dropped from the same height of 2 m, and percent error between them.

Further free fall experiments were done with four objects to see how the time of fall changes with height of fall. So, these four objects were dropped from a different height of 1 m to see comparative results of the same objects when they were dropped from 2 m heights. The effect of height on free fall can be seen in the TABLE 4.

Table 4: It shows eight objects those show deviation from free fall concepts and show large percent error in their experimental time of fall and final velocity.

TABLE 4: Deviated Objects from free fall				
Objects	Texp(s)	% error in Texp	Vf_exp(m/s)	% error in Vf
Open Umbrella	1.25	95.31	12.26	95.89
Plastic Bowl	1.01	57.81	9.91	58.28
Foam Cup	1.13	76.25	11.07	76.77
Plain Paper	2.10	227.81	20.58	228.78
Bookmark	1.16	81.25	11.38	81.78
Sticker	1.31	105.00	12.87	105.60
Feather	1.68	162.81	16.50	163.58
Balloon with air	2.08	225.63	20.44	226.58

DISCUSSION

Based on these Data, results and Figures, it came out that 8 objects those have higher volume, larger size and lighter weight, do not follow free fall concepts and showed presence of air resistance and deviation from free fall concepts. Out of these 8 objects, there were FIVE objects, the plain paper, balloon with air, feather, paper sticker and open umbrella showed most deviated results in time of free fall Texp and their final velocity Vexp with higher percent errors. This indicates the presence of air resistance which can be represented as air resistance acceleration (a_{air}) as shown in the equations # 5 & 6 in the method section. The presence of air resistance can be shown in the form of Free Body Diagram (FBD). The FBD of the object that follows free fall without any air resistance and for the object that doesn't follow free fall concept and shows presence of air resistance can be seen in the Figure 2B.

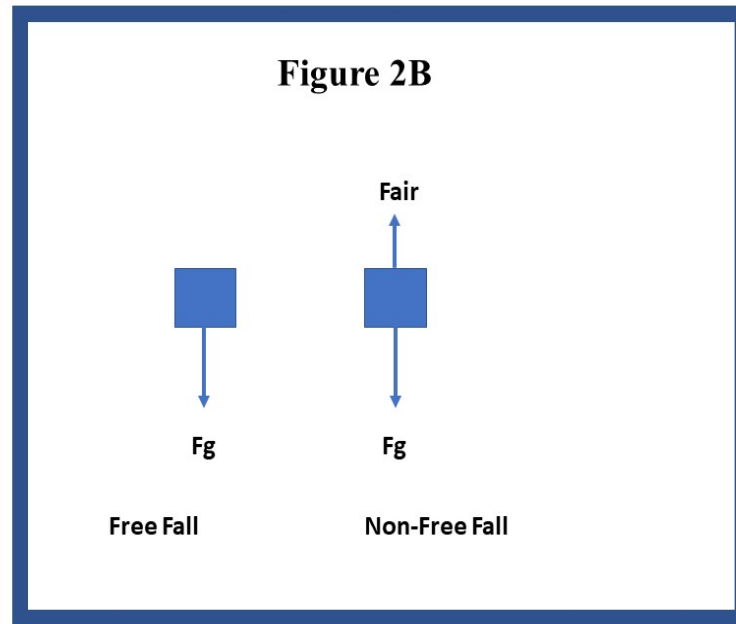


Figure 2B: It shows a schematic of a Free Body Diagram (FBD) of a freely falling object and a non-freely falling object that has air resistance.

This figure shows a non-free fall must have an air resistance force (F_{air}) upwards along with its gravitational force downwards (F_g). Since the deviated objects show presence of air resistance, the air resistance and final experimental acceleration of fall as a_{air} and a_{exp} were calculated following equations # 5, 6 as shown in the equation and method section for all deviated 8 objects. Figure 3A shows different value of acceleration of fall than gravity which indicate the presence of air resistance.

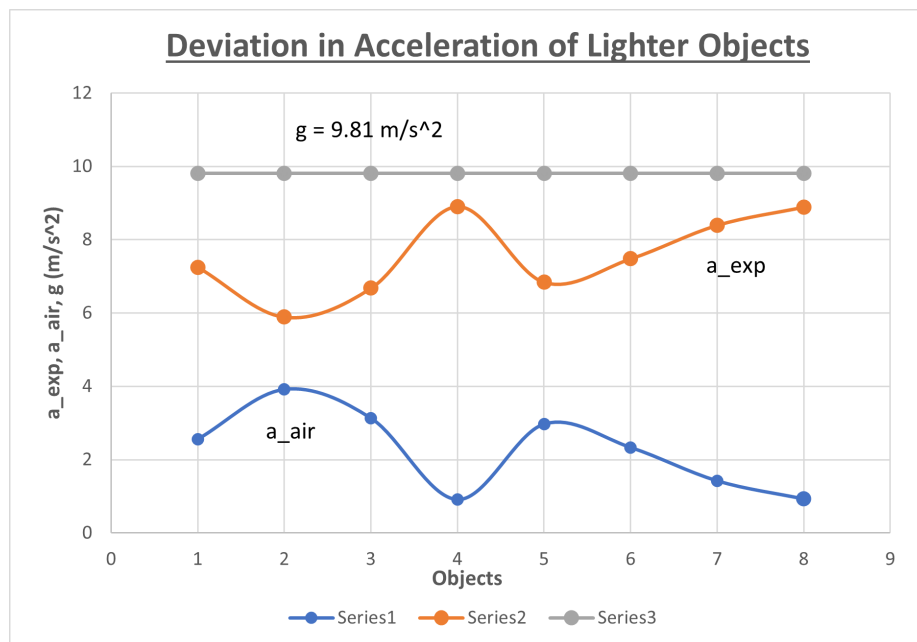


Figure 3A: It shows graph of eight objects those show deviation from free fall and their acceleration of fall are different than gravity. These are mostly either are lighter objects or objects those hold air in them.

When the air resistance constant called as “k” was calculated for all deviated objects, it was found that open umbrella gives the highest value. These results can be seen in Figure 3B which shows presence of air resistance in deviated objects along with air resistance constant values in their free fall. When air resistance was calculated, all 7 other deviated objects showed least air resistance force except one which is open umbrella. Since open umbrella has ability to hold more air, so showed maximum air resistance with highest value of air resistance constant $k = 0.1324 \text{ kg/s}$ [3] and satisfies why parachutes are used to slow down fall during skydiving.

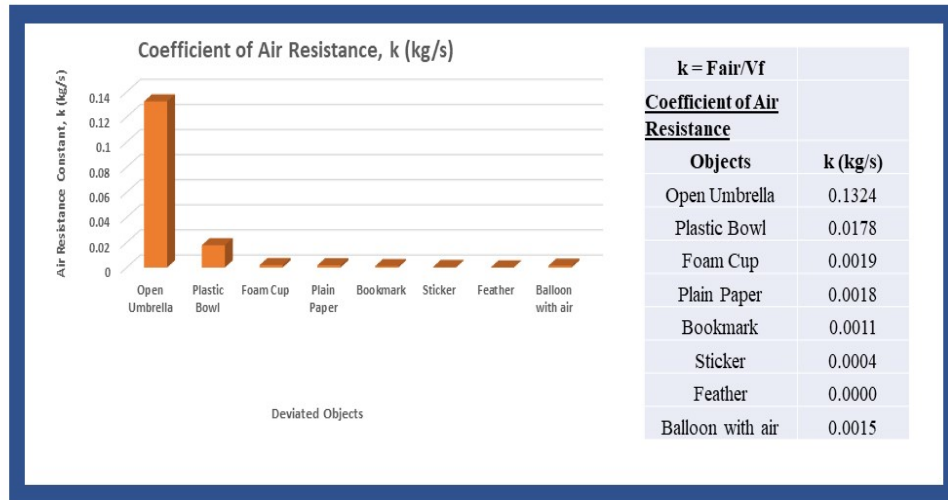


Figure 3B: It shows air resistance constant for eight deviated objects in the form of bar graph.

The effect of height on free fall was also tested by dropping FOUR objects from a lower height and it was found that when objects are dropped from lower height, they take less time to fall and hit ground with less speed, shown in Figure 4A. These results were compared with the results of free fall of the same four objects when they were dropped from 2 m height and shown in the same Figure 4A.

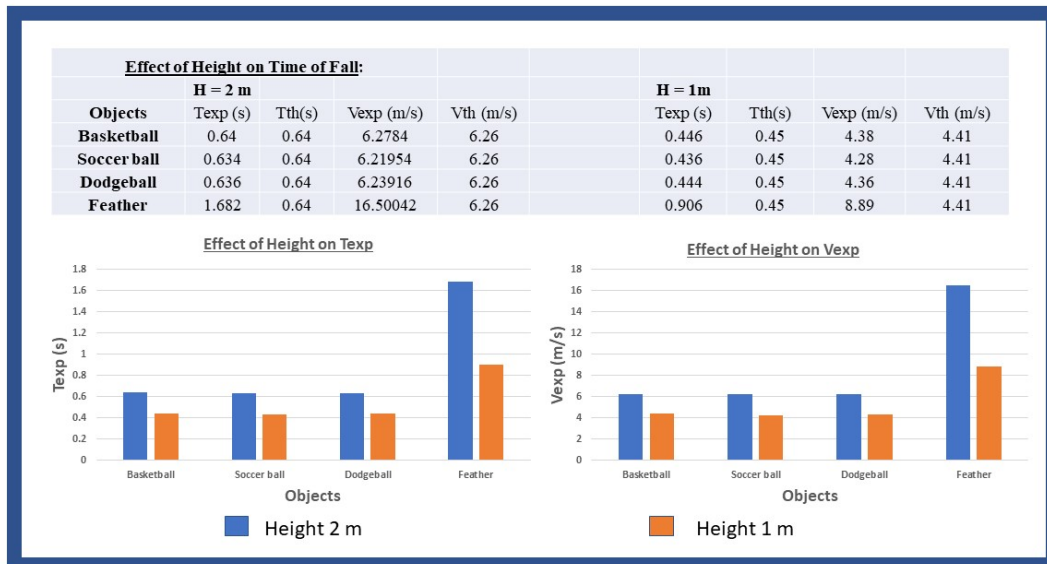


Figure 4A: It shows the effect of height on free fall as effect in experimental time of fall (Texp) and experimental final velocity at the time objects hit the ground (Vexp) for four objects those were dropped from a lower height of 1 m and then compared with the height of fall of 2 m.

The effect of mass and weight of the objects on free fall was also tested by dropping heavier objects from the same height and it was found that the mass or the weight of the object does not affect the time of fall or final velocity of the object no matter how heavy they are (based on the weight those were used in this experiment), shown in Figure 4B.

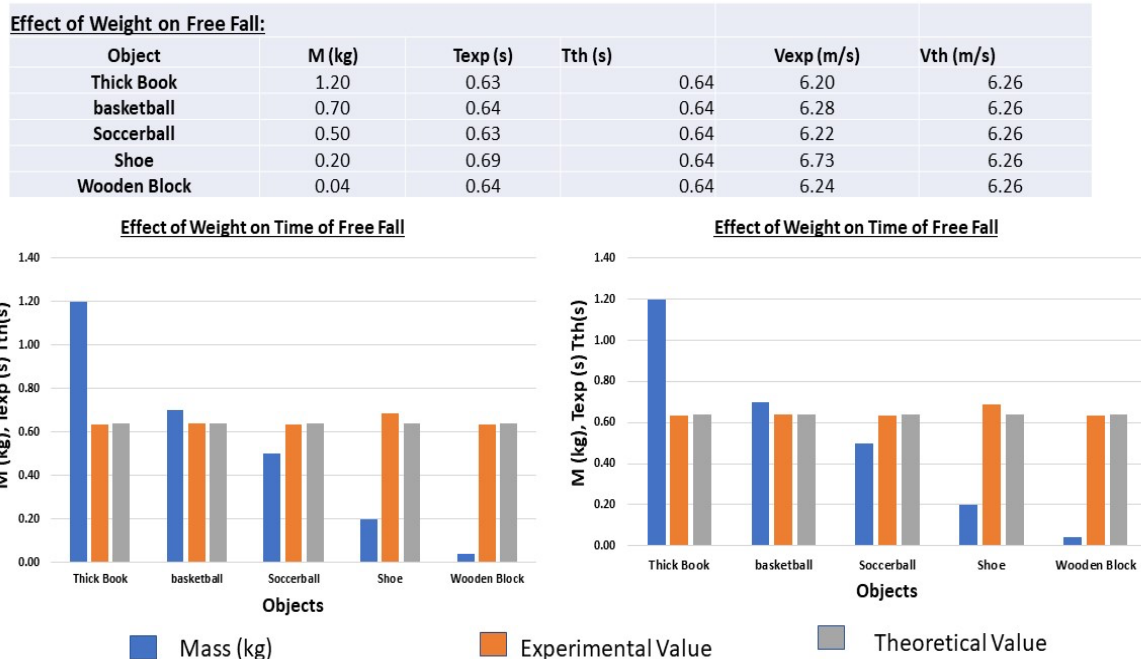


Figure 4B: It shows the effect of mass and weight on free fall and experimental time of fall (Texp) and experimental final velocity at the time objects hit the ground (Vexp). No deviation was found on objects based on their mass.

After applying these methods and concepts of free fall, it came out that the weight of the object doesn't affect time of fall unless object is very light or have larger volume. Different shape and size objects take same time of fall unless they are large in shape to hold air. All objects hit ground with highest velocity when they reach to the ground as gravity pulls them every moment. Objects take longer time to fall if they are dropped from higher height. In real world, all falls do not follow free fall i.e., raindrop, a falling leaf, a falling bird feather and open parachute. Based on the size of object, if they can hold more air or if they are lighter than air, they have air resistance. The most important factors those are causing effect in giving error in experimental time of fall are 1) air resistance and 2) human reaction time if manual collecting device is used for time of fall. The factor of reaction time is omitted by subtracting reaction time from the time of fall collected from the device, but air resistance cannot be controlled even though experiments were done inside the house where effect of wind, air pressure, temperature and humidity were same during all experiments. This indicates that if object is light enough or have larger volume to hold air, object takes longer time to fall because of air resistance. [6]

CONCLUSION

So, as concluding remark, it can be said that all falls those are seen in the real world are not free fall, but they can be non-free fall as well. Free fall can be seen in real world as: 1) A basketball falling from the basket, 2) A stone falling from a hill, 3) raw pizza dough that has been tossed up into the air and falls back down. A sky diver must have knowledge on the concept of free fall

to know when decrease acceleration during fall and open their parachute to see some good examples of non-free fall where air resistance is significant can be seen in real world as 1) Leaves falling from trees in yard, 2) freely falling a bird feather, 3) a plain paper falling, 4) a person falling with parachute. In Star War movie, the hero had a stunt of free fall when he falls from a hill, can it be a free fall! [7]

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References

- [1]. Pictures are taken from Internet.
- [2]. "Introduction to Free Fall Motion", *The Physics Classroom*, January 28, 2021, <https://www.physicsclassroom.com/class/1DKin/Lesson-5/Introduction>.
- [3]. *Falling Body with Air Resistance*, January 28, 2021, <http://oregonstate.edu/instruct/mth252h/Bogley/w02/resist.html>.
- [4]. "Experiment", *How Fast Your Brain Reacts To Stimuli*, January 28, 2021, <https://backyardbrains.com/experiments/reactiontime>.
- [5]. "Tracker Video Analysis and Modeling Tool for Physics Education", *Tracker*, January 28, 2021, <https://physlets.org/tracker/>.
- [6]. "How does air temperature and humidity affect the speed of a moving object?", *Quora*, January 28, 2021, <https://www.quora.com/How-does-air-temperature-and-humidity-affect-the-speed-of-a-moving-object>.
- [7]. "The Fall - Star Wars", *The Phantom Menace*, *StarWars.com*, January 28, 2021, <https://www.starwars.com/video/the-fall>.